To: NuMI Beam Enthusiasts
From: D. A. Jensen
Re: Toroid Ratio Monitoring
Date: June 25, 2014, update Sept 10, 2014

This is an update of the previous version, extending the time period through the end of the 2014 run on Sept. 5, 2014. The ratio of TRTGTD/TR101D have remained very stable suggesting that the toroid calibrations have remained stable throught this running period.

From time to time I have been checking the ratios of the NuMI beam toroids and the DCCT. As there are 3 devices, TRTGTD, TR101D and the DCCT, the ratios are sensitive to calibration drifts of the individual devices. If the ratios are constant, one might expect that each of the devices is stable. This monitoring does NOT address the absolute calibration of these devices.

It has been agreed for some time that the nominal intensity of the NuMI beam is the intensity as measured using TRTGTD.

These checks are done by taking a full day, or a large fraction of a day, of data and plotting the ratios of the intensity monitors. A sample plot from June 10, 2014 is shown in Figure 1. The lower three plots are the ratios of the intensities as measured by the three devices. The distributions are fit to a Gaussian. The three ratios are of course redundant. All the information is contained in any two of the ratios.

Figures 2 and 3 shows two of the ratios. The first ratio, which is the 'extraction efficiency', shows some jumping around. The DCCT which is used to measure the internal beam (Ibeam23[5]) is new this run. So it went out of calibration, and was subsequently recalibrated (the jump in March 2014). The ratio of TRTGTD/TR101D (the 'transport efficiency') is shown in the lower plot. This ratios of the ratio of intensities as measured by the NuMI toroids. It is clearly stable to well better than a half a percent.

Of course the transport efficiency, like the extraction efficiency, is 1 to very high accuracy. There is extensive instrumentation to detect losses. Except when devices are inserted into the NuMI beam for monitoring, there are no measurable losses, so the extraction and transport efficiency are in fact 1. The ratios of the intensity monitors are therefore monitoring the gains of the intensity monitors.

When beam is delivered to the Main Injector via the Recycler, I:BEAM is used instead of IBEAM23(5). These two measurements of the MI intensity are equivalent.

To conclude, TRTGTD remains the valid measure of beam intensity throughout this period.

The total number of protons delivered, based on TRTGTD, was 3.26×10^{20}. This is slightly larger than the number of protons measured using I:BEAM due to the calibration issue shown in Figure 4.

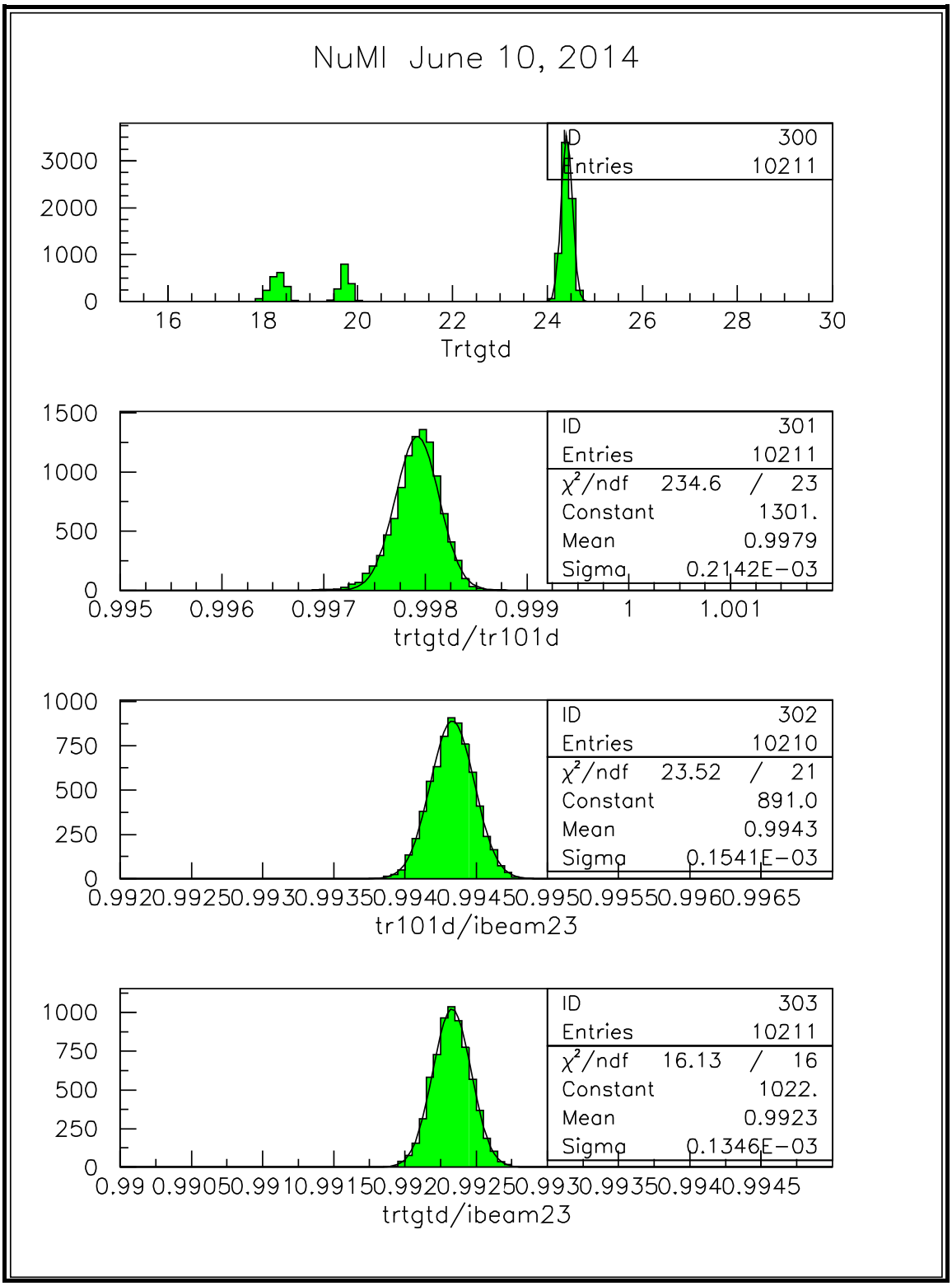

Figure 1 Samples of ratios of intensity monitors. Top box shows the intensity as measured using trtgtd in units of E12 protons/spill.

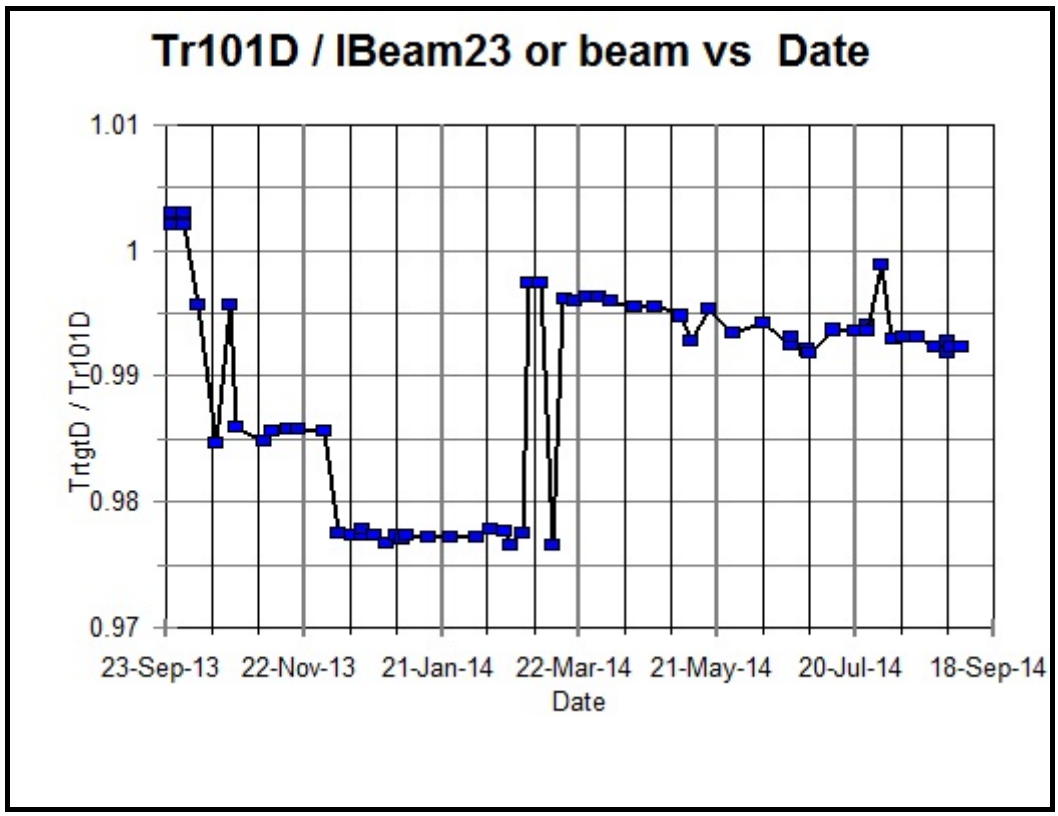

Figure 2 Ratio of TR101D to the Internal MI Beam.

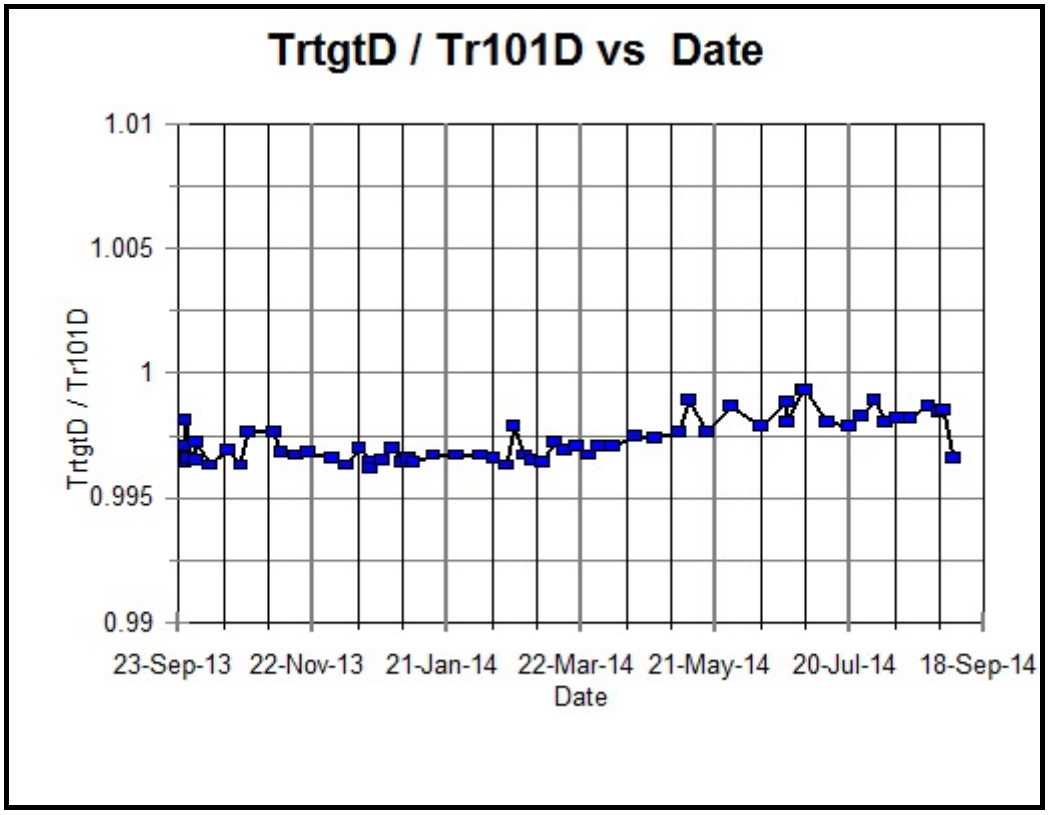

Figure 3 Ratio of TRTGTD/TR101D vs time.

The Main Injector has been running at two intensities, for the June 22 sample these intensities are 16E12 and just below 25E12. The ratios of the NuMI toroids at these two intensities are shown in the two plots below. The ratios are 0.9988 and 0.9986. Clearly the two modes have no effect on the intensity measurement ratios..

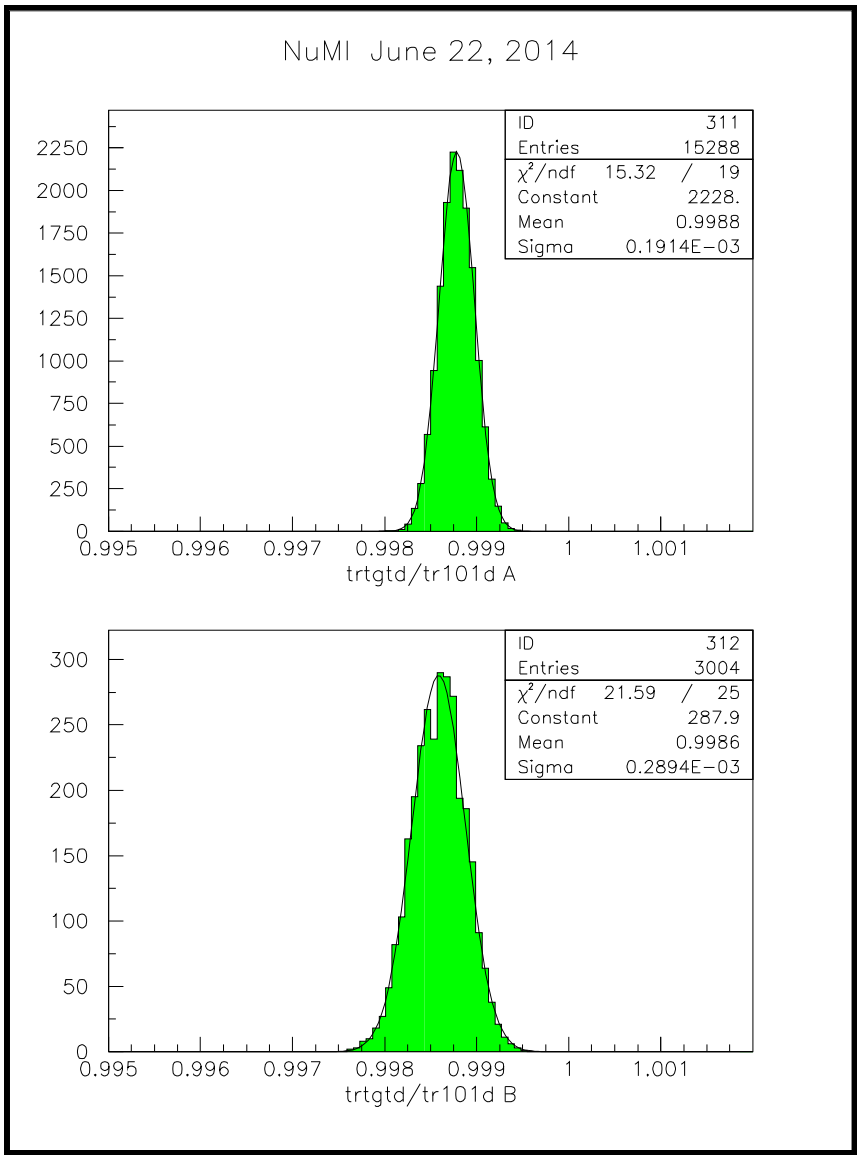

Figure 4 Top - numi toroid ratio for I ~ 25 E12, lower, ratio for intensity ~17 E12